Externalities, environmental quality, and allocation

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Externalities can be explained by the existence of competing uses for public goods with zero prices. The model presented includes the competing roles of the environment as a provider of public consumption goods and as a receptor of emissions from production activities. Scarcity prices of a situation of optimal environmental allocation are derived.

In an often quoted article *Scitovsky* (1954) characterized external economies as being "somewhat bucolic in nature having to do with bees, orchards and woods". And he added: "This, however, is no accident; it is not easy to find examples from industry" (p. 145). Since *Pigou*'s (1932) analysis, external diseconomies also have led a somewhat bucolic and neglected life in economic theory being analyzed occasionally in welfare and micro-economics. The consideration of the environmental issue makes it necessary to put externalities into the center of economic analysis.

Externalities are defined as technological or non-market interdependencies among economic activities. In the following we concentrate on externalities originating in production activities. Then an externality exists[1] if

$$Q_i = F_i\,(K_i, A_i; Q_j) \tag{1}$$

or

$$\frac{\partial Q_i}{\partial Q_j} \gtrless 0 \quad \text{with } i \neq j \tag{1'}$$

with Q denoting output, K capital and A labor of activities i or j.

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[1] Definition (1′) is not exhaustive since it does not include the "technological" effect of a production activity on the utility of consumers. To include this case let Q_i indicate quantities produced and Q_i^C quantities consumed. Then the utility function for an individual houselhold is given by $w_i = w_i\left(Q_i^C; Q_j\right)$. An externality exists if

$$\frac{\partial w_i}{\partial Q_j} \gtrless 0 \quad \text{for } j = i \text{ or } j \neq i \quad (1'') .$$

This type of externality, howewer, has not been discussed in great detail by traditional analysis.

In traditional economic analysis, the expression $\partial Q_i / \partial Q_j \gtreqless 0$ was taken as given and was not analyzed any further. It is the contention of this paper that the analysis of the interrelation among Q_i and Q_j leads to some additional economic insights. Section I defines the problem. In section II, an allocation model is developed. Section III describes the implications of the model and IV mentions some of its limitations and possible extensions.

I. The Problem

Externalities exist, since economic activities are linked to each other via some nonmarket variables. In the past, economists have not realized that one of the empirically most relevant technological links between economic activities is the environmental system[2]. Externalities can then be explained by introducing intervening environmental variables between Q_i and Q_j, namely variables such as river systems, ground water systems, meteorological systems. The relevant variable linking these environmental media with the economic system are effluents emitted into the environment.

In order to analyse the relevance of the environmental system for the existence of externalities, it is necessary to recognize that the environmental system is related to economic activities in three different ways:

— it provides inputs to production processes such as oxygen for combustion processes or water for industrial cooling purposes,

— it serves as a receptor of effluents which are generated as joint products of production (and consumption) activities,

— it represents a public consumption good providing such basic goods as air, water and amenities of the landscape.

These different uses of environmental media are competing with each other. Two cases of competing uses may be distinguished analytically (*Siebert* 1973):

i) Assume a specific environmental medium is used for one purpose only, such as the water of a river system for industrial cooling. Using the water upstream may influence its cooling quality downstream. This case of competing uses relates to the fact that an environmental good has a given capacity for a specific use and that demand for this type of commodity or service may be greater than the capacity

[2] Some externalities between consumption activities (i. e. the social determination of utility functions) can be explained by the social system. Labor market externalities (training workers by existing firms for newly acquired activities) run via labor mobility and the labor market. Agglomeration economies are mainly transportation and information advantages.

given. This phenomen which also may be observed with respect to environmental consumption goods such as national parks, wilderness areas and other recreation facilities has been labelled the congestion problem of public goods (*Havemann* 1973, *Rothenberg* 1970).

ii) In reality, most environmental media can be used for more than one purpose. Then in addition to the congestion problem, competing uses of the environment exist between different production activities (winning coal in surface mining may affect agricultural productivity by lowering the ground water level), between different consumption purposes (swimming in a lake may influence the quality of drinking water) and between production and consumption activities (oxygen used for combustion is not available for consumption).

The central cause of competitive uses of the environment consists in its role as a receptor of pollutants and as a provider of public consumption goods. A public consumption good may be defined by a vector of characteristics, such as the temperature of a lake, purity of its water expressed by its pollution content etc. Emitting effluents into environmental media directly affects the characteristics of environmental consumption goods.

Environmental links are only one factor explaining the existence and the magnitude of externalities. One additional factor determining the occurrence of externalities is the fact that environmental media can be used for a set of competing uses as a public good, i. e. at a zero price. Treating the environment as a common property resource (*Kneese* 1971) is a built-in-factor for the generation of externalities. Although it cannot be ruled out that in some activities the generation of effluents is not sensititive to a scarcity price for the use of the environment, it can be assumed that the occurrence of negative externalities can be reduced by developing a price system for environmental uses. The conclusion for economic policy is to change the public good character of the environment by levying an effluent charge on the produces of the externality. The following model determines the effluent charge as a shadow price for pollutants by explicitly taking into account some of the competing uses of the environment.

II. The Model

Assume a production function with sectoral output (Q_i) depending on capital and labor input (K_i, A_i) and the quantity of j-pollutants (P_j) ambient in the environment

$$Q_i = \varphi_i [K_i, A_i; P_j] \tag{1''}$$

with

$$\frac{\partial \varphi_i}{\partial K_i}, \frac{\partial \varphi_i}{\partial A_i} > 0, \frac{\partial^2 \varphi_i}{\partial K_i^2}, \frac{\partial^2 \varphi_i}{\partial A_i^2} < 0$$

and

$$\frac{\partial \varphi_i}{\partial P_j} < 0, \frac{\partial^2 \varphi_i}{\partial P_j^2} < 0$$

The negative marginal productivity of pollutants indicates physical damage of one unit of pollutants in production activities.

The quality of l different environmental consumption goods (U_l) is influenced both by the quantity of j-pollutants (P_j) ambient in the environment and by the use intensity (N_l) of the public good

$$U_l = \gamma_l (P_j, N_l) \tag{2}$$

with

$$\frac{\partial \gamma_l}{\partial P_j} < 0$$

and

$$\frac{\partial \gamma_l}{\partial N_l} \leqslant 0 \quad \text{if} \quad N_l \gtreqless \overline{N}_l$$

where $\overline{N}_l$ denotes the capacity of the public good l. If the use intensity remains below or just reaches the capacity, using the public good does not influence its quality. The quality is, however, affected, as soon as the use intensity surpasses capacity (*Havemann* 1973).

Eqs. (1‴) and (2) involve the aspect of competing uses a) by assuming that the level of pollution affects production and the quality of public consumption goods and b) by assuming that congestion influences the quality of public goods.

The quantity of a pollutants (P_j) ambient in the environment depends on r pollutants emitted (E_r), pollutants reduced by abatement activities (Z_r) and by pollutants degraded by the environmental system ($\bar{Z}_r$).

$$P_j = \Phi_j (E_r, Z_r, \bar{Z}_r) \tag{3}$$

with

$$\frac{\partial \Phi_j}{\partial E_r} \geqslant 0 \qquad \text{if} \quad E_r \gtreqless \bar{Z}_r$$

and

$$\frac{\partial \Phi_j}{\partial Z_r} \leqslant 0 \qquad \text{if} \quad E_r \gtreqless \bar{Z}_r$$

$\bar{Z}_r$ is the assimilative capacity of the environment for pollutant r, i. e. the ability of environmental subsystems to degrade pollutant r. Although it is conceivable to increase $\bar{Z}_r$ by public investment such as instream-aeration of river systems to augment the oxygen content, $\bar{Z}_r$ is here regarded as a given factor.

The function Φ_j indicates that pollutants emitted and pollutants ambient in an environmental medium are not identical[3]. Emissions are diffused by environmental media; i. e. they are transported to other areas, and they are changed in their nature by reaction processes in the environment. Consequently, Φ can be interpreted as a diffusion function.

For a more detailed analysis, the diffusion function would have to be regionalized, i. e. it should indicate the spatial extent of diffusion. Also, it should indicate how different pollutants interact with each other in the environment (i. e. synergism).

The diffusion function is a central problem for environmental policy since the target variables of environmental policy are the immission levels, but policy instruments must be directed at the emission. Transforming the target variable into an instrument variable requires information on the diffusion process.

Pollutants are emitted by production activities and by the consumption of private and public goods representing joint products of these activities for a given technology.

(4)
$$E_r = \sum_i \alpha_{ri}(Q_i) + \sum_i \beta_{ri}(Q_i) + \sum_l \varepsilon_{rl}(N_l)$$

with

$$\frac{\partial \alpha_{rl}}{\partial Q_i} \geqslant 0$$

denoting the marginal generation of pollutants r in production activity i,

$$\frac{\partial \beta_{ri}}{\partial Q_i} \geqslant 0$$

[3] Only in a simplified case, when diffusion is not considered, i. e. $j = r$, Eq. (3) can be interpreted as a definition

$$P_j = E_j - Z_j - \bar{Z}_j$$

denoting the marginal generation of pollutants r in the consumption of the private good i [4], and

$$\frac{\partial \varepsilon_{rl}}{\partial N_l} \geqslant 0$$

denoting the marginal generation of pollutants r in the consumption of the public good l.

Pollutants emitted (E_r) may be abated by an environmental protection agency by using capital and labor

$$Z_r = \eta_r (K_r, A_r) \tag{5}$$

with

$$\frac{\partial \eta_r}{\partial K_r}, \frac{\partial \eta_r}{\partial A_r} > 0$$

Alternatively, Eq. (5) may be defined with respect to immissions being reduced.

The resource constants are given by

$$\begin{aligned} \sum_i K_i + \sum_r K_r &= \bar{K} \\ \sum_i A_i + \sum_r K_r &= \bar{A} \end{aligned} \tag{6}$$

with $\bar{K}$, $\bar{A}$ denoting the quantity of resources available.

Finally, assume for simplicity, that the intensity of use of the public consumption good is given by

$$N_l = N_l (M) \tag{7}$$

where M denotes such factors as population, population density and the availability of private goods[5].

Assume an environmental agency wants to maximize total welfare of the society by taking explicitly into consideration environmental qual-

[4] No distinction is made between commodities produced and consumed, i. e. it is assumed that commodities produced are consumed in the same period.

[5] Eq. (7) can only be interpreted as a rudimentary demand function for the public good. Eq. (7) can be justified as a formal way to include some aspects of the public good 'environment'. It certainly does not pretend to solve the problem, how a demand function for a public good can be constructed from individual utility functions or a social welfare function. — The quantity of private goods available for consumption may influence the demand for public goods if private and public goods are complementary to each other (cars are needed to visit a national park) or can be substituted against each other (private and public swimming pools).

ity as a public consumption good. It has to maximize the objective function

(8) $$W = W(q_i, u_l)$$

with vector q denoting the private goods Q_i and vector u standing for the public goods U_l.

For the System described by Eqs. (1‴) - (7), this yields the following Lagrangean expression

(9)
$$\begin{aligned} L = {} & W(q_i, u_l) \\ & - \sum_i \lambda_{Q_i} [Q_i - \varphi_i (K_i, A_i, P_j)] \\ & - \sum_l \lambda_{U_l} [U_l - \gamma_l (P_j, N_l)] \\ & - \sum_j \lambda_{P_j} [P_j - \Phi_j (E_r, Z_r, \bar{Z}_r)] \\ & - \sum_r \lambda_{E_r} [E_r - \sum_i \alpha_{ri} (Q_i) - \sum_i \beta_{ri} (Q_i) - \sum_l \varepsilon_{rl} (N_l)] \\ & - \sum_r \lambda_{Z_r} [Z_r - \eta_r (K_r, A_r)] \\ & - \lambda_K [\sum_i K_i + \sum_r K_r - \bar{K}] \\ & - \lambda_A [\sum_i A_i + \sum_r A_r - \bar{A}] \\ & - \sum_l \lambda_{N_l} [N_l - N_l (M)] \end{aligned}$$

III. Solution and Implications

Maximization of Eq. (9) yields the following optimality conditions[6]

(10.1) $$\lambda_{Q_i} = \frac{\partial W}{\partial Q_i} + \sum_r \lambda_{E_r} \left(\frac{\partial \alpha_{ri}}{\partial Q_i} + \frac{\partial \beta_{ri}}{\partial Q_i} \right)$$

(10.2) $$\lambda_{U_l} = \frac{\partial W}{\partial U_l}$$

(10.3) $$\lambda_K = \lambda_{Q_i} \frac{\partial \varphi_i}{\partial K_i}$$

(10.4) $$\lambda_K = \lambda_{Z_r} \frac{\partial \eta_r}{\partial K_r}$$

(10.5) $$\lambda_A = \lambda_{Q_i} \frac{\partial \varphi_i}{\partial A_i}$$

[6] The optimality conditions obtained by calculating the first derivative of L with respect to the different λ' s are not written out.

(10.6)
$$\lambda_A = \lambda_{Z_r} \frac{\partial \eta_r}{\partial A_r}$$

(10.7)
$$\lambda_{P_j} = \sum_j \lambda_{Q_i} \frac{\partial \varphi_i}{\partial P_j} + \sum_l \lambda_{U_l} \frac{\partial \gamma_l}{\partial P_j}$$

(10.8)
$$\lambda_{E_r} = \sum_j \lambda_{P_j} \frac{\partial \Phi_j}{\partial E_r}$$

(10.9)
$$\lambda_{Z_r} = \sum_j \lambda_{P_j} \frac{\partial \Phi_j}{\partial Z_r}$$

(10.10)
$$\lambda_{N_l} = \lambda_{U_l} \frac{\partial \gamma_l}{\partial N_l} + \sum_r \lambda_{E_r} \frac{\partial \varepsilon_{rL}}{\partial N_l}$$

with L standing for the different l public goods.

Interpreting the different Lagrange-multipliers as scarcity prices we obtain the following results.

1. The shadow price of pollutants ambient in the environment (λ_{P_j}) is determined according to (10.7) by the social damage caused by one unit of pollutants. Social damage consists of two components. First it includes social damage in the production sector being measured by physical marginal damages of a unit of pollutants in the different production activities ($\partial \varphi_i / \partial P_j$) times the evaluation of the physical damage (λ_{Q_i}). Secondly, it includes the deterioration of the l public consumption goods. The deterioration of a public consumption good is given by physical marginal damage ($\partial \gamma / \partial P_j$) times the evaluation of one unit of the environmental commodity (λ_{U_l}). Observe that the shadow price λ_{P_j} is negative due to $\partial \varphi_i / \partial P_j < 0$ and $\partial \gamma_l / \partial P_j < 0$.

2. Pollutants ambient in the environment cannot be directly affected or controlled by environmental policy. Instrument variables cannot directly be attached to immissions, but can only influence or control emissions. Consequently, the shadow price of emissions is the strategic variable for environmental policy. The shadow price of an emission of the type r (λ_{E_r}) is given by (10.8) as the marginal tendency to transform one unit of emission r into the different pollutants j and the shadow prices of these pollutants j. In addition to information on the social damage caused by one unit of pollutant j, environmental policy needs information on the diffusion and environmental interaction of pollutants in order to calculate the shadow price of pollutants. Only in the special case of emissions being identical to immissions, the shadow price of emissions is identical to that of imissions. Observe that since $\lambda_{P_j} < 0$, the shadow price of emissions is negative. The producer of pollutants has to pay a penalty for generating pollutants.

3. Of considerable importance for policy solutions is the determination of the relative price structure for different emissions due to the fact that the producer of pollutants may substitute emissions with a high penalty by emissions with a lower shadow price. Consider two emissions r and R. The shadow price relation is given by

$$\text{(11)} \qquad \frac{\lambda_{E_r}}{\lambda_{E_R}} = \frac{\Sigma \lambda_{P_j} \dfrac{\partial \Phi_j}{\partial E_r}}{\Sigma \lambda_{P_J} \dfrac{\partial \Phi_J}{\partial_{E_R}}} = \frac{\sum_j \left(\sum_i \lambda_{Q_i} \dfrac{\partial \varphi_i}{\partial P_j} + \sum_l \lambda_{U_l} \dfrac{\partial \gamma_l}{\partial P_j} \right) \dfrac{\partial \Phi_j}{\partial E_r}}{\sum_J \left(\sum_i \lambda_{Q_i} \dfrac{\partial \varphi_i}{\partial P_J} + \sum_l \lambda_{U_l} \dfrac{\partial \gamma_l}{\partial P_J} \right) \dfrac{\partial \Phi_J}{\partial_{E_R}}}$$

The shadow price relation of pollutants should account for i) differences in transformation and diffusion processes and ii) for differences in social damage being caused by the emissions. A similar price structure problem arises with respect to different environmental media. This aspect is, however, not included in the model.

4. The shadow price of pollutants abated (10.9) is given by the term $\partial \Phi_j / \partial Z_r$ indicating the change in the different immissions j due to a reduction of one unit of emission r times the shadow prices of the pollutants j! Since both expressions in (10.9) are negative, the shadow price of pollutants reduced is positive. It corresponds to the marginal social damage prevented by the abatement of pollutants.

5. Assuming that $\partial \Phi_j / \partial E_r = - \partial \Phi_j / \partial Z_r$, i. e. that one unit of emission of type r increases immissions of the types j by the same amount as one unit of emissions of type r abated reduces immissions, we have from (10.4), (10.8) and (10.9).

$$\text{(12)} \qquad \lambda_{E_r} = - \frac{\lambda_K}{\dfrac{\partial \eta_r}{\partial K_r}}$$

The input requirement function $K_r = \eta_r{}^{-1} Z_r$ is an inverse to the abatement function; due to the inverse function rule $\dfrac{1}{\partial \eta_r / \partial K_r}$ represents marginal capital requirement for reducing one unit of pollutants. Multiplying this expression by λ_K defines marginal abatement costs. From (12) and the analogous expression to (12) with respect to labor, from (10.7) and (10.8) the effluent charge for an emission r should be set so that

$$\text{(12')} \qquad - \sum_j \frac{\partial \Phi_j}{\partial E_r} \left(\sum_i \lambda_{Q_i} \frac{\partial \varphi_i}{\partial P_j} + \sum_l \lambda_{U_l} \frac{\partial \gamma_l}{\partial P_j} \right) = \frac{\lambda_K}{\dfrac{\partial \eta_r}{\partial K_r}} = \frac{\lambda_A}{\dfrac{\partial \eta_r}{\partial A_r}}$$

DOI https://doi.org/10.3790/schm.95.1.17 | Generated on 2024-07-23 19:14:13

The effluent charge should be set such that social marginal damage is equal to marginal costs of abatement[7].

In Fig. 1 a emissions E_r are measured along the x-axis and it is assumed that social marginal damage increases progressively under the assumptions made (curve DD'). Let OT indicate the total quantity of emissions. Then emissions reduced Z_r are measured by moving from T to the origin. Marginal abatement costs increase progressively under the assumption made (curve CC').

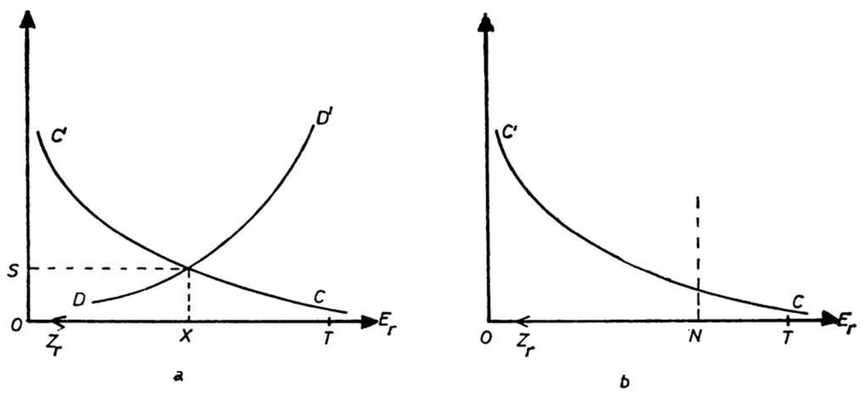

Fig. 1

OX indicates the level of emissions that is optimal with respect to the benefit from environmental quality and the social costs of a lower quantity of private goods Q_i; OS denotes the shadow price for the emission r[8].

6. Eq. (12′) specifies the information requirements of an effluent charges system, namely

i) information on the quantity of emissions,

ii) information on the diffusion and transformation of emissions into pollutants ambient in the environment,

iii) social damage both in physical and in value terms of one unit of pollutants,

iv) marginal costs of abatement.

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[7] Observe that $\lambda_K / \frac{\partial \eta_r}{\partial K_r}$ indicates both partial and total marginal abatement costs for efficient production. Compare *H. Schneider* (1973), p. 166.

[8] Observe that Fig. 1 a does not consider the diffusion problem.

DOI https://doi.org/10.3790/schm.95.1.17 | Generated on 2024-07-23 19:14:13

Baumol (1972), *Baumol* and *Oates* (1972) and *Tietenberg* (1973 b) have argued that for practical policy solutions a standard price approach is sufficient, i. e. environmental policy defines environmental quality standards in terms of immission norms as fixed policy targets, such as *ON* in figure 1 b. As can be seen from figure 1 b, the only information necessary to calculate the effluent charges is to know the marginal abatement costs (and for the implementation of the charges system: to know the quantity of emissions). Even if abatement costs are not fully known, environmental policy may establish the desired environmental quality in a trial-and-error process by readjusting the effluent charge until finally the desired environmental situation is reached.

Observe that the standard price approach changes the Lagrangean function (9). Standards are either expressed in terms of the quality of the public consumption good or in terms of the quantity of pollutants ambient in the environment P_j. Take the second case. Then an additional restraint is added with $P_j \leqslant \bar{P}_j$ and the problem is to reach these standards with minimum costs (*Tietenberg* 1973 a). Unless $\bar{P}_j$ is set by accident in accordance with the optimal solution of (9), a different optimum will result. The less strict information requirement of the standard price approach involves the risk of non-optimal solutions.

7. The implications on factor prices (10.3 - 16.6) indicate the well — known conditions that factor prices should be equal to the marginal value product of factors and that the marginal value product of factors should be identical in the competing uses of a factor, e. g.

$$\lambda_{Q_i} = \frac{\partial \varphi_i}{\partial K_i} = \lambda_{Z_r} \frac{\partial \eta_r}{\partial K_r} \tag{13}$$

A unit of capital should be allocated between the production sector (i) and the abatement activity (r) in such a way that the contribution to increasing the value of the objective function is identical in both uses.

8. Commodity prices are corrected for the social damage caused by the generation of pollutants. In contrast to the traditional *Pigouvian* analysis of externalities starting from (1′) where we would have for the pollution intensive commodity I

$$\lambda_{Q_I} = \frac{\partial W}{\partial Q_I} + \sum_i \lambda_{Q_i} \frac{\partial Q_i}{\partial Q_I}, \tag{14}$$

we are now able to specify the term $\sum_i \lambda_{Q_i} \frac{\partial Q_i}{\partial Q_I}$. As can be seen from (10.1) and (10.7) the social damage of activity I is given by the quantity of pollutants generated by activity I per unit of output ($\partial \alpha_r / \partial Q_I$) times the evaluated reduction of output in other activities and the evaluated damage in terms of the environment as a consumption good.

Compared to (14), (10.1) introduces the quantity of emissions (and immissions) as an intervening variable between Q_i and Q_I. If information on emissions can be secured at reasonable costs, the approach presented introduces a strategic variable for environmental policy.

The objective of environmental policy must be to attribute social damage to the polluter. This can be achieved by charging a shadow price for pollutants. Consider commodities i with no generation of pollution and good I with

$$\frac{\partial \alpha_{rI}}{\partial Q_I} > 0 \text{ and for simplicity } \frac{\partial \beta_{rI}}{\partial Q_I} = 0 \; .$$

Then the price relation of commodities is given by

$$(14') \quad \frac{\lambda_{Q_i}}{\lambda_{Q_I}} = \frac{\dfrac{\partial W}{\partial Q_I}}{\dfrac{\partial W}{\partial Q_I} + \sum_r \sum_j \dfrac{\partial \alpha_{rI}}{\partial Q_I} \dfrac{\partial \Phi_j}{\partial E_r} \left(\sum_i \lambda_{Q_i} \dfrac{\partial \varphi_i}{\partial P_j} + \sum_l \lambda_{U_l} \dfrac{\partial \gamma_l}{\partial P_j} \right)}$$

If environmental policy succeeds in attributing social damage to the polluter the price relation in (14′) will rise. The incentive to produce commodity i has increased and the incentive to produce good I has decreased.

9. From (10.3) we have the well — known implication

$$(15) \quad \frac{\lambda_{Q_i}}{\lambda_{Q_I}} = \frac{\dfrac{\partial \varphi_I}{\partial K_I}}{\dfrac{\partial \varphi_i}{\partial K_i}}$$

Assume that due to environmental policy the price relation is changed in favor of commodity i. Then the relation of marginal productivities of capital must change, too. Under the assumptions made this can only be achieved if capital is reallocated among sectors i and I. Ceteris paribus, $\partial \varphi_I / \partial K_I$ must rise and $\partial \varphi_i / \partial K_i$ must fall. This can only be achieved by using less capital in I and more in i.

The reallocation of factors between sectors i and I is steered by factor prices. Let $\lambda^0_{K_i} = \lambda^0_{K_I}$ denote factor prices given in the initial situation in the two sectors. If due to environmental policy the price of commodity I falls, capital earnings must fall in I due to (10.3) for a given allocation of capital, i. e. for a given $\partial \varphi_I / \partial K_I$. Consequently resources will migrate to sector i.

If the ceteris paribus assumption is released, one should observe that the introduction of environmental policy does not only change the price relation between commodities i and I, but also increases the shadow price for pollutants abated. Consequently, factor earnings in the abatement activities will rise. Factors will migrate to abatement activities being withdrawn from sectors i and I. Observe, however, that it is sufficient for (15) to rise that $\partial \varphi_I / \partial K_I$ will rise more than $\partial \varphi_i / \partial K_i$. The result will be that sector I will use (absolutely or) relatively less capital than in the initial situation[9].

10. The model explicitly takes into account the quality of the l public consumption goods and specifies a shadow price system that allocates the environment to the competing uses. The quality of the public consumption good is affected by pollution and the use intensity of the public good in the case of congestion.

Assume that the demand for the waste-receiving role of the environment increases and production activities emit a greater quantity of pollutants. The resulting environmental damage requires a higher (negative) implicit price for pollutants and a rise in the effluent charges for emissions. The demand for the waste receiving function, i. e. emissions, will be reduced with the scarcity price allocating the public good environment to the competing uses.

From (10.10) an implicit price also exists for using the environment as a public consumption good under two circumstances: First, when using the public good generates pollutants, the implicit price is determined by the quantity of pollutants generated in using the public good and the shadow price of the pollutant. Second, when congestion occurs, increasing the use of a given environmental good necessitates an implicit price consisting of the effect of the additional use on environmental quality times the evaluation of the environment. Increasing the use intensity of the public good makes it necessary to let users pay a penalty in order to discourage using the public good.

It must be left open whether a shadow price for using the environment as a consumption good is a practicable policy instrument. It may be questioned whether sufficient exclusion technologies exist and whether it is socially desirable to introduce a price mechanism for the allocation of public consumption goods to individual uses. Conceivably, other allocation mechanisms have to be developed for that problem. However, the proposed shadow price λ_{N_l} shows the implicit scarcity

[9] On resource effects of environmental policy, compare *H. Siebert* (1974 a, b).

price from efficiency considerations and thus is helpful in indicating the trade-off between efficiency goals and the policy objectives such as equity associated with alternative allocation mechanisms.

IV. Limitations and possible extensions

Some limitations and possible extensions of the proceeding analysis should be pointed out.

i) The model presented does not consider whether the allocation policy proposed is consistent with a general equilibrium in the economy. Especially, it is not analyzed whether the behavior of subsystems of the economy such as entrepreneurs, households and the environmental protection agency will eventually lead to the described optimum (*Tietenberg* 1973 a and b).

ii) The model does not consider the reaction behavior of polluters such as substitution of production procedures, substitution of inputs, variations in the product mix, investment for the reduction of emissions and the shifting of effluent charges.

iii) A precondition for the policy conclusions suggested is that emissions can be measured at reasonable costs. It should be pointed out that practical experience with an effluent charge system exists in the field of water quality management, e. g. in the water management cooperatives of the Ruhr area in Germany (*Klevarick* and *Kramer* 1973) and the Agence de Bassins in France (OECD 1972).

iv) The model does not consider the spatial aspect of environmental policy, i. e. the question whether environmental policy instruments such as effluent charges should be differentiated regionally or should be applied nationally in a uniform manner (*Siebert* 1974 c and *Stein* 1971).

v) The model concentrates on allocation efficiency and does not consider other targets of economic policy such as distributional justice.

vi) Finally, the conclusions reached are the result of a static model. Dynamic problems such as the accumulation of pollutants over time are not taken into consideration. Also, the interrelation of environmental quality and economic growth is neglected. To include these problems necessitates maximization of a welfare function for a planning period and using other procedures of maximization such as control theory[10].

[10] On public goods and economic growth, compare *H. Schneider* (1972). On the problem of public bads over time compare *d'Arge* and *Kogiku* (1973), *Keiler, Spence* and *Zeckhauser* (1971) and *Mäler* (1974).

Summary

Externalities exist since economic activities are linked to each other via nonmarket variables. One important factor explaining the occurrence of negative externalities are competing uses of the environment. — A model is constructed that determines effluent charges as shadow prices for pollutants by explicitly taking into account some of the competing uses of the environment. Specifically, it is assumed that production activities generate pollutants and that a pool of pollutants ambient in environmental media negatively affects productivity. Also, immissions and use intensity influence the quality of environmental public consumption good. Emissions can be abated by an environmental protection agency. Welfare of the society is defined with respect to private goods and environmental quality. The shadow prices for emissions, immissions, pollutants abated and commodities are derived. Possible extensions of the model are discussed.

Zusammenfassung

Externe Effekte existieren, weil ökonomische Aktivitäten über Nicht-Marktsysteme miteinander verknüpft sind. Ein sehr wichtiges „Nicht-Marktsystem" sind die Umweltmedien, für die in der Regel Verwendungskonkurrenz vorliegt. Die nicht gelöste Verwendungskonkurrenz begründet negative externe Effekte. Das konstruierte Modell zieht diese Verwendungskonkurrenz explizit in Betracht. Insbesondere wird angenommen, daß die Produktionsaktivitäten Schadstoffe generieren und daß ein „Schadstoffpool" sich negativ auf die Produktivität auswirkt. Ferner beeinflussen Immissionen (und die Nutzungsintensität) die Qualität des öffentlichen Konsumgutes „Umwelt". Emissionen können von einer Umweltbehörde durch Einsatz von Ressourcen beseitigt werden. Die Wohlfahrt einer Gesellschaft hängt von privaten Gütern und der Umweltqualität ab. Die Schattenpreise der Emissionen, der Immissionen, der beseitigten Schadstoffe und der Güter werden abgeleitet und interpretiert. Mögliche Erweiterungen des Modells werden vorgeschlagen.

References

d'Arge, R. C. and *K. C. Kogiku* (1973), Economic Growth and the Environment, Review of Economic Studies, 46 (1973), p. 61 - 77.

Balassa, B. (1973), Regional Policies and the Environment in the European Common Market, Weltwirtschaftliches Archiv, 109 (1973), p. 402 - 417.

Baumol, W. I. (1972), On Taxation and the Control of Externalities, American Economic Review, 62 (1972), p. 307 - 322.

Baumol, W. I. and *W. J. Oates* (1972), The Instruments for Economic Policy, Paper delivered on the Conference "Economics of Environment" held by Resources for the Future and National Bureau of Economic Research, Chicago Nov. 10./11, 1972.

Førsund, F. R. (1972 a), Allocation in Space and Environmental Pollution, Swedish Journal of Economics, 74 (1972), p. 19 - 34.

— (1972 b), Externalities, Environmental Pollution and Allocation in Space: A General Equilibrium Approach, 1972 mimeographed.

Haveman, R. H. (1973), Common Property, Congestion, and Environmental Pollution. The Quarterly Journal of Economics, 87 (1973), p. 278 - 287.

Keeler, E., M. Spence and *R. Zeckhauser* (1971), The Optimal Control of Pollution, Journal of Economic Theory, 4 (1971), p. 19 - 34.

Klevarick, A. K. and *G. H. Kramer* (1973), Social Choice on Pollution Management: The Genossenschaften, Journal of Public Economics, 2 (1973), p. 101 - 146.

Kneese, A. V. (1971), Environmental Pollution: Economics and Policy, American Economic Review, Papers and Proceedings, 61 (1971), p. 153 - 166.

Kneese, A. V. and *B. T. Bower* (1968), Managing Water Quality: Economics, Technology and Institutions, Baltimore 1968. Deutsch: Die Wassergüterwirtschaft. Wirtschaftstheoretische Grundlagen, Technologien, Institutionen, München 1972.

Mäler, K. G., Environmental Economics: A Theoretical Inquiry, Baltimore 1974.

OECD (1972), Environmental Committee, Subcommittee of Economic Exports, An Examination of the Polluter Pays Principle based on Case Studies, Paris 1972.

Pigou, A. C. (1932), The Economics of Welfare, 4. Aufl., London 1932.

Rothenberg, J. (1970), The Economics of Congestion and Pollution: An Integrated View, American Economic Review, 60 (1970), p. 114 - 121.

Scitovsky, T. (1954), Two Concepts of External Economies, Journal of Political Economy, 62 (1954), p. 143 - 151.

Siebert, H. (1973), Das produzierte Chaos. Ökonomie und Umwelt, Stuttgart 1973.

— (1974 a), Comparative Advantage and Environmental Policy: A Note, Zeitschrift für Nationalökonomie, 34 (1974), p. 397 - 402.

— (1974 b), Environmental Protection and International Specialization, Weltwirtschaftliches Archiv, 110 (1974), p. 494 - 508.

— (1974 c), Regional Aspects of Environmental Policy Instruments, Paper Prepared for the OECD, Beiträge zur empirischen Wirtschaftsforschung, Mannheim, Discussion Paper No. 49/74, 1974.

Schneider, H. (1972), Staatsaktivität und optimales Wachstum, in W. Albers (Hrsg.), Probleme der Staatsverschuldung, Schriften des Vereins für Socialpolitik, Neue Folge, Bd. 61, Berlin 1972, p. 113 - 141.

— (1973), Mikroökonomie. Eine Einführung in die Preis-, Produktions- und Wohlfahrtstheorie, München 1973.

Stein, J. L. (1971), The 1971 Report of the President's Council of Economic Advisers: Micro-Economic Aspects of Public Policy, American Economic Review, 61 (1971), p. 531 - 537.

Tietenberg, T. H. (1973 a), Controlling Pollution by Price and Standard Systems: A General Equilibrium Analysis, The Swedish Journal of Economics, 75 (1973), p. 193 - 203.

— (1973 b), Specific Taxes and the Control of Pollution: A General Equilibrium Analysis, The Quarterly Journal of Economics, 87 (1973), p. 503 - 522.